UNITED STATES MARINE CORPS

LESSON PLAN

ATMOSPHERIC STABILITY

INTRODUCTION:

1. Gain Attention. When air rises, it cools and eventually may produce clouds or precipitation. Why do clouds vary in size, and why does any resulting precipitation vary so much? The answers are closely related to the *stability* of the atmosphere.

2. Overview. The purpose of this period of instruction is to provide the student with a fundamental understanding of obtaining and utilizing atmospheric stability.

3. Introduce Learning Objectives.

    a. Terminal Learning Objective. With the aid of references and given a Skew-T Log P Diagram, appropriately state the levels of stability on the current environmental profile.

    b. Enabling Learning Objective(s). Without the aid of, but in accordance with the references, the student shall:

        (1) Determine the type of atmospheric stability at a given level.

        (2) State how atmospheric stability is enhanced.

        (3) Describe the relationship between vertical air motion and stability.

4. Method/Media. This period of instruction will be taught using the lecture method with the aid of a Macromedia Flash presentation "QMMPH1-Introduction to the Dynamics of the Earth's Atmosphere".

5. Evaluation. The student(s) shall be evaluated by physically demonstrating learned knowledge by creating local area forecasts.

TRANSITION. As air rises, it will cool and expand until it reaches the dew-point where clouds will form. Do clouds always form? Does the air parcel always reach its dew point? The following topics introduce basic stability concepts and how certain situations can aid to or prohibit the development of relatively poor weather.

BODY:

1. Determining Atmospheric Stability. The stability of the atmosphere is determined by measuring the air temperature at various heights throughout the atmosphere. This temperature profile is known

as the *environmental lapse rate.* The environmental lapse rate is the actual temperature of the atmosphere, as recorded by radiosondes and aircraft, and should not be confused with adiabatic temperature changes. Adiabatic temperature changes are the changes in temperature that a parcel of air would experience when moving vertically throughout the atmosphere. (*Refer to QMMPH1-018 & QMMPH1-019 for a detailed review on The adiabatic process and lapse rates*)

TRANSITION. With the background of how one can determine stability, we will now focus on three fundamentals of stability (stable and unstable air) and the conditions of the atmosphere: absolute stability, absolute instability, and conditional instability.

2. Types of Stability.

a. Characteristics of rising air. A parcel of air can be thought of as having a thin flexible cover over it that allows it to expand but prevents it from mixing with the surrounding atmosphere (a hot air balloon is a good example). If this parcel of air were forced to rise, its temperature would decrease because of expansion. By comparing the temperature of the parcel to the temperature of the surrounding air, one can determine its stability.

(1) Stable Air. If the parcel of air were cooler than the surrounding environment, it would be more dense (recall that cold air is more dense than warm air); and if allowed to do so, it would sink to its original position. This type of air is classified as *stable air,* and resists vertical movement.

(a) Figure 1 illustrates how the stability of the atmosphere is determined. Consider a situation in which the prevailing environmental lapse rate is 5˚C per 1000 meters. Under this condition, when the air at the surface has a temperature of 25˚C, the air at 1000 meters will be 5˚C cooler, or 20˚C, whereas the air at 2000 meters will have a temperature of 15˚C, and so forth. By further examination of Figure 1, it can be determined that the air parcel is rising at the dry adiabatic lapse rate of 10˚C per 1000 meters. Notice at 1000 meters, the parcel of air is 5˚C cooler than the environment, it would be denser; therefore, sink back to its original position. Thus, we say that the air near the surface is potentially cooler than the air aloft and therefore the air parcel will not rise on its own.

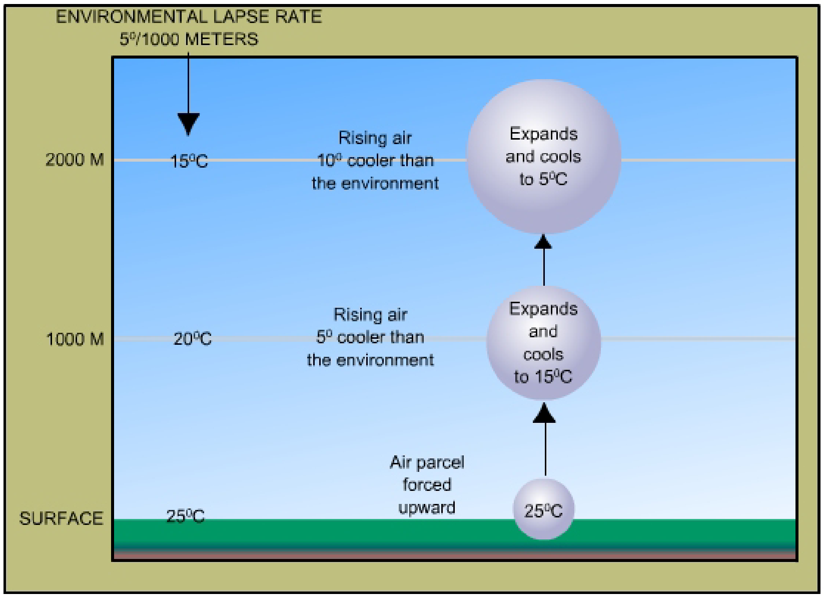

Figure 1 – Unsaturated parcel of air cooling at the dry adiabatic lapse rate 10˚C/1000 meters. Because the temperature of a rising parcel of air is cooler than the environment, it will sink back to its original position.

(b) By similar reasoning, if the air at 1000 meters is 20˚C and subsided, adiabatic heating would increase its temperature 10˚C by the time it reached the surface, making it warmer than the surrounding air. Its buoyancy would cause it to return to its original position. The state described is still known as stable and will resist vertical movement, downward or upward.

(2) Unstable Air. When the rising parcel of air is warmer than its surrounding environment, the parcel would continue to rise until it reached a point where its temperature matched the temperature of the surrounding environment. This type of air is classified as *unstable air*. A hot-air balloon is a classic example, rising so long as the balloon is warmer and less dense than the surrounding air.

b. Absolute Stability. Absolute stability will prevail when the environmental lapse rate is less than the moist adiabatic lapse rate. Figure 2 depicts absolute stability by using an environmental lapse rate of 5˚C per 1000 meters and a moist adiabatic lapse rate of 6˚C per 1000 meters. The temperature of the surrounding air at 1000 meters is 15˚C and that the rising air has cooled by expansion to 10˚C and so it is now denser. Even if this air were forced above the condensation level, it would remain cooler and denser than its environment and have a tendency to return to its original position at the surface.

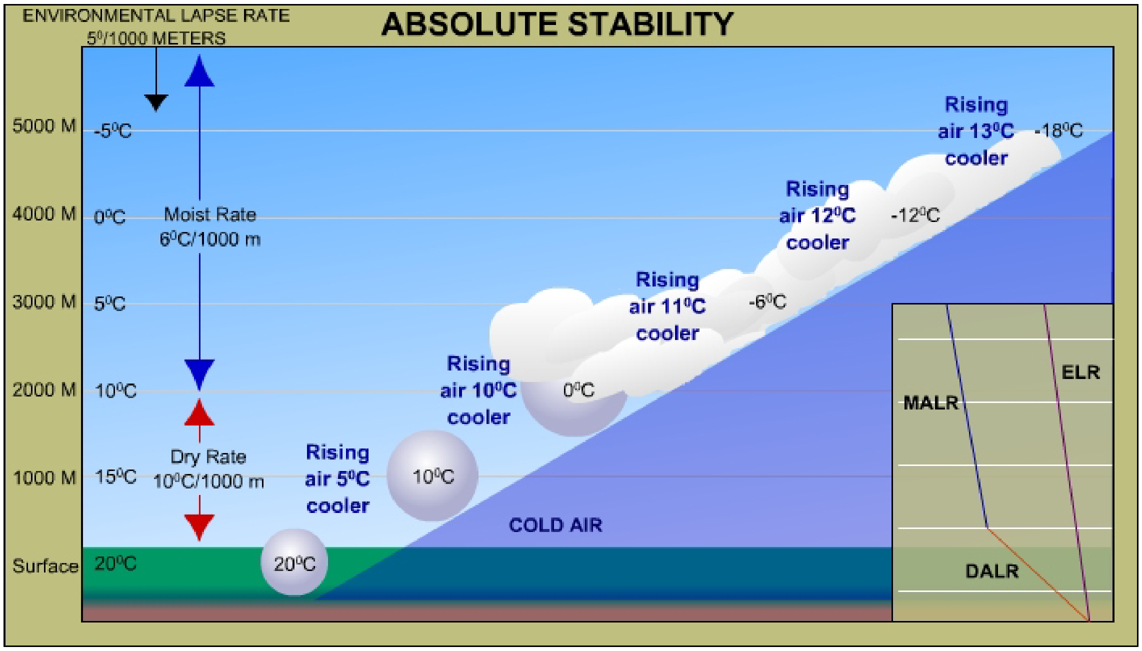

Figure 2 - Absolute stability exists when the environmental lapse rate is less than the moist and dry adiabatic lapse rates.

(2) The most stable conditions occur when the temperature in a layer of air actually increases with height. When this reversed condition occurs, it as known as an *inversion*.

(3) Temperature inversions frequently occur on clear nights as a result of radiational cooling at the Earth's surface. Under these conditions an inversion is created because the ground and the air immediately above the ground will cool more rapidly than the air above.

(4) Temperature inversions also occur in the winter when the warm moist air from the Gulf of Mexico invades the cold, snowed covered surfaces of the Midwest. Anytime warmer air overlies cooler air, the result is an extremely stable layer that resists vertical movement.

c. Absolute Instability. Absolute instability exists when the environmental lapse rate is greater than the dry adiabatic lapse rate. By referencing figure 3, the ascending parcel of air is always warmer than its environment and will continue to rise as long as it remains less dense, or warmer, than the surrounding environment.

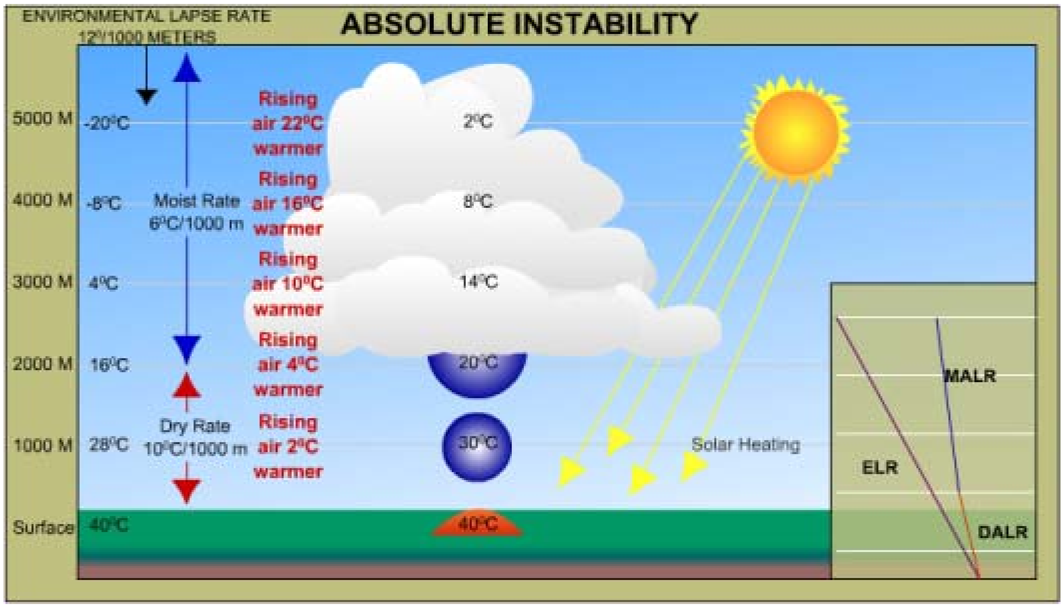

Figure 3 – Absolute instability can result when intense surface heating causes the lower levels of the atmosphere to heat faster than the air above it, which, in turn produces a steep environmental lapse rate and unstable conditions.

(1) Absolute instability occurs most during the warmest months of the year and on clear days when solar heating is most intense. Under these circumstances, the lower-most part of the atmosphere is heated to a much higher degree than the air aloft. This will result in a steep environmental lapse rate and a very unstable atmosphere.

(2) Instability produced mainly by strong surface heating is generally confined to the first few thousand meters of the atmosphere. Above this height, the environmental lapse rate assumes a more "normal" value. The temperature begins to decrease more slowly with increasing altitudes, creating a more stable temperature regime. Consequently, clouds produced by surface heating lack great vertical extensions and rarely are associated with violent weather.

d. Conditional Instability. Conditional stability exists when moist air has an environmental lapse rate between the moist and dry adiabatic lapse rates (between 5˚C and 10˚C per 1000 meters).

(1) The "conditional" part of the term comes into play when considering the saturation level of the parcel. The atmosphere is said to be *conditionally unstable* when it is stable with respect to an unsaturated parcel of air, but unstable with respect to a saturated parcel of air.

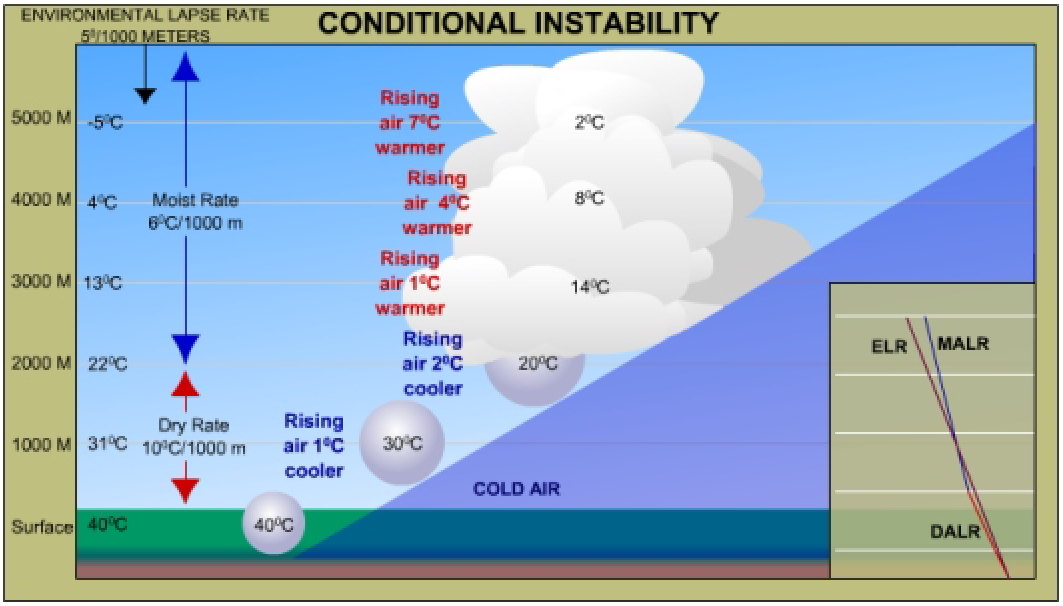

Figure 4 – The parcel of air is cooler than the surrounding environment as it is forced up a cold frontal boundary. When it reaches the lifted condensation level, the parcel becomes warmer than the surrounding environment and rises freely on its own.

(2) Use Figure 4 to notice that the rising parcel of air is cooler than the surrounding air for the first 2000 meters. With the release of latent heat above the lifted condensation level, the parcel becomes warmer than the surrounding air. From this point forward, the parcel will continue to rise without any additional forcing. Thus, conditional instability depends on whether or not the rising parcel of air is saturated. The word "conditional" is used because the air must be forced upward before it reaches the level where it becomes unstable and rises on its own.

TRANSITION. After discussing the different types of stability, it is important to recognize and understand how stability changes.

3. Atmospheric stability changes.

a. Most processes that alter stability result from temperature changes caused by vertical or horizontal air movement. In general, any factor that increases the environmental lapse rate renders the air more unstable, whereas any factor that reduces the environmental lapse rate increases the air's stability.

(1) The higher, or steeper, the environmental lapse rate, the more rapidly the temperature drops with increasing altitude. Therefore, any factor that causes the air near the surface to warm in relation to the air above decreases the stability. Instability is enhanced by:

(a) Intense solar-heating warming the lower-most portion of the atmosphere.

(b) The heating from an air mass below as it passes over a warmer surface.

(c) General upward movement of air caused by processes such as orographic lifting, frontal wedging, and convergence.

(d) Radiational cooling from cloud tops.

(2) Any factor that causes the surface air to be chilled results in the air becoming more stable. Recall that the most stable conditions occur with inversions. Stability is enhanced by:

(a) Radiational cooling of the Earth's surface after sunset.

(b) The cooling of an air mass below as it passes over a cooler surface.

(c) General subsidence within a column of air.

TRANSITION. We now know that sable air resists vertical movement and unstable air ascends freely on its own without any additional forces. By knowing this, how do these facts manifest themselves in our daily weather?

4. Effects of stability on daily weather.

a. When stable air is forced aloft, the resulting clouds are widespread and have little vertical extent compared to their horizontal extent (i.e. stratus clouds). Precipitation, if any, is light to occasionally moderate. Widespread fog is another indicator of stability.

b. Clouds associated with unstable air possess moderate to great vertical extents (i.e. cumuliform clouds) and usually are associated with moderate to heavy precipitation.

c. We should now be able to conclude that on an overcast and dreary day with light drizzle, that stable air was forced aloft. Or, on a day with big, puffy, build-up clouds appearing to be growing as if hot air were surging upward, we can conclude that the atmosphere is unstable.

TRANSITION. By knowing the effects of stability and its impacts to daily weather conditions or phenomena, we should now be able to comprehend the processes that are taking place in the atmosphere when we are observing on the surface.

OPPORTUNITY FOR QUESTIONS:

1. Questions from the Class. At this time are there any questions from the class relating to the material that has just been presented to you?

2. Questions to the Class. There are no questions for the students at this time.

SUMMARY: In summary, the stability of the air determines the type of weather a location will experience. A thorough understanding of the types of stability and the respective effects will allow for a sound fundamental atmospheric application.

REFERENCE.

MOAF Course Textbook (N61RCB1-ST-102) Physics I, Chapter 5, pgs. 13-15. Rev. October 2002.

Frederick K. Lutgens and Edward J. Tarbuck. The Atmosphere: An Introduction to Meteorology 9th ed. New Jersey: Pearson Education Inc., 2004.